MICROPROGRAMMABLE PROCESSORS APPLIED TO TELEMETRY PROCESSING SYSTEMS

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Summary This paper briefly analyzes the application of modern microprogram techniques in the computerized telemetry processing environment. It shows these technique s can attain a flexibility in design and application previously unavailable.

Introduction With the advent of easily programmable on-board telemetry multiplexers, it is possible to change the format and content of telemetry data streams almost at will. This, plus the increasingly higher data rates, have made flexibility in real-time telemetry processing systems of paramount importance.

In particular, those processing systems with the mission of supporting a multitude of vehicle types and formats, in real-time, are faced with the problem of providing general data reduction facilities with a wide range of capabilities.

This paper will discuss, first, typical existing computerized telemetry processing systems and secondly, the use of microprogrammable processors in like systems. The use of microprogrammable processors in telemetry systems is shown to improve system performance and increase flexibility.

Configuration 1 (Software Compression/Analysis) This configuration, used primarily for low data rates (100KBS), consists of two major components; a synchronizing/formatting module and a central processing module.

Synchronizing and Formatting Module This component is the formatting and synchronizing portion of the system. In an analog system, this module synchronizes and digitizes the incoming data based on control from the central processing system (CPS) and presents the digitized data to the CPS via either a data bus (channel) or direct memory access.

In a PCM system, this module synchronizes and decommutates (syllablizes) the incoming data stream, presenting it to the CPS via either data bus or direct memory access. The formatting and synchrontztng module in a PCM system may be, in fact, a programmable decommuntation station that requires little in the way of CPS control other than initialization and statusing.

Central Processing System The second component is the central processing system. It may be any one of the various general purpose computers and the proper peripheral devices available for the application to be handled.

In this low data rate configuration, if data compression techniques are used, they are performed by a computer program. Another CPS program or subprogram accomplishes the analysis tasks.

Also, in this configuration, sub and super commutation of parameters is handled in the CPS. This normally involves large tables of parameter pointing and identification information.

Configuration 2 (Hardware Compression) This system configuration is composed of three major modules: 1) synchronizing and formatting module; 2) data compression module; and 3) central processing system. This system configuration is used for high rate $\geq$1024 KBS PCM data. Refer to Figure2.

Synchronizing and Formatting Module This system component has as its main function synchronization/decommutation of the incoming telemetry data stream, as in the first configuration. However, one additional function has been added: The identification of data parameters. This component has, in its decommutation program, the information to handle sub and super commutation and applies the same systems identification (i.e., tag) to every sample from the same transducer. This additional tag is necessary to maintain continuity through the total system and is transmitted as output with the respective data parameters.

Data Compression Module This systems module uses hardware to apply data compression algorithms to the identified data input from the synchronization module. See Figure 3. The data compressor, normally, is attached to the synchronizing/format module by a data bus that transmits both data and systems identification. The compressor, upon receipt of data/ID, fetches from core memory the appropriate algorithm for compression. For those parameters that fail the compression test, data and identification are transmitted to the CPS.

Central Processing System Since, in this configuration, the CPS is absolved from the basic responsibilities of identification and compression, more meaningful data analysis may be accomplished. Typically, this configuration allows more data base manipulation and interactive man/ machine interface than the first configuration.

Microprogramming Microprogrammable processors are well suited to the telemetry industry. These devices are capable of performing those functions in telemetry systems normally performed by special purpose hardware devices. Functions, such as synchronization, data compression and engineering unit conversion, can be controlled by a microprogrammable “Firmware” program and can easily be changed or expanded with a programming change rather than a hardware modification.

When a microprogrammable processor performs the same function as another hardware device, it is said to be “emulating” that device. The device being emulated is called the target machine.

The advantages of microprogramming have been known since 1951 when M. V. Wilkes coined the term “microprogramming”.[1] Prior to the advent of medium and large scale integration (MS1, LSI) it was not economically feasible to implement microprogramming on a popular basis. However, presently there are several microprogrammable processors on the market.

Microprogramming is basically one method of organizing the control architecture of a central processor. Microprocessors usually consist of a high speed (50-100 nanosecond) memory called control store, core memory, microinstruction control logic and an arithmetic unit. Figure 3.

Control store contains the sequence of microinstructions that execute predetermined functions or algorithms performed by the “target machine”: Such as a synchronizer or data compressor.

Control storage is available in two basic types: 1) Read only memory (ROM). This type of memory is non-volatile; however, the memory is also incapable of being easily changed should it be desired at a later date. 2) Read/Write (R/W). Read/Write storage is volatile; however, its prime consideration in systems design is that the memory may be loaded dynamically at any time giving the capability of changing the firmware resident in the microprogrammable processor (changing the emulation).

Core memory is the storage medium for holding data, target machine instructions or algorithm directives.

Microinstruction control logic controls the execution sequence of instructions from control store.

The arithmetic unit is the portion of the processor that performs arithmetic and logical operations.

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[1] P. M. Davies, Readings in Microprogramming , IBM Systems Journal No. 1, 1972

It is important to note that the “target” machine may be the microprogrammable processor itself. That is to say, the microprogrammable processor may contain in its control store the series of instructions necessary to “emulate” some alien architecture; or it may be programmed as an extremely high speed computer in its own right.

The following discussions will utilize the alien architecture technique. However, synchronizing formatting modules used in systems at data rates greater than 1. 024MBS, must execute algorithmic instructions directly from control storage so that the data rates may be achieved.

The following discussion will examine how microprogrammable processors could be used in lieu of the special purpose hardware in the telemetry configurations presented in Figures 1 and 2.

Synchronization/Formatting Function The use of a microprograrnmable processor in the synchronization/formatting function enables the user to handle a multitude of formats; and depending upon his data rates, he may be able to incorporate other systems functions in this module. Studies have shown that at data rates up to 256 KBS the data compression function can be added to the synchronizing/formatting module, thus, in smaller systems alleviating the central processing system from this trivial task.

Since a microprogrammable processor has the capability of utilizing its own core memory storage for decommutation/synchronization programs, it is totally feasible to handle data formats in which discrete bits separated and strewn throughout the frame could be assembled and compressed as unique data parameters passed to the central processing system. In some applications, this would reduce the workload of the central processing system by as much as 15%.

The Data Compression Module The use of a microprogrammable processor as a data compression module adds the capability of redefining compression algorithms, as required by changing systems requirements and changing data formats. An additional important feature is the capability to chain the compression algorithms and execute a program based on the premise that a data parameter either passes or fails its compression algorithm.

The interconnection between the data formatting system and the data compression system may be accomplished in one of two manners: either via a data bus, or by sharing common magnetic core storage so that the inherent buffering necessary in high data rate systems is available to both the formatting and synchronizing module.

Engineering Units Conversion Module Engineering units conversion modules (EUC) are defined as being those hardware/firmware components of a telemetry processing system that execute algorithms for conversion of telemetry data to their corresponding engineering units. These modules generally have the capability to linearize and normalize raw telemetry data. The use of a microprogrammable processor as an EUC module has primarily the following additional features. It allows the user, because of its inherent flexibility, the capability of redefining these linearizations, normalizations and EUC algorithms as he desires. It is also possible to string EUC modules to develop in the system that level of conversion desired in the front-end hardware.

Figure 4 shows a basic configuration utilizing microprogrammable processors as the main components of the special function devices.

Summary If existing systems requirements do not change, formats never vary, and data rates remain constant, there is no need to change telemetry system components. It has been the experience of the author that very little, if any, of these requirements remain static. With the flexibility inherent in a microprogrammic processor, changes in requirements may be satisfied with very little or no systems impact. The use of a microprogrammable processor as a “synchronizer/formatter/data compressor” for low rate data for example, does not preclude the addition of another microprogrammable processor in the system to perform data compression for higher rate data. This would eliminate the data compression function from the first microprogrammable processor and allow it to perform faster synchronization logic. Thus, an upgrade of a telemetry processing system is enacted by simply adding a microprogrammable processor.

A change in data content that levies a new compression requirement on a system does not have to be satisfied with a CPS systems software change or data compressor hardware change if the data compression is being performed by a microprogrammable processor. The generation of a new “hardware” compression algorithm is a matter of simply adding/changing a microprogrammable processor firmware subroutine.

The amount of sophisticated processing to be done as an engineering units conversion function requires simply a throughput analysis of the system. Once the analysis arrives at a “time per parameter”, the main constraint for this module is defined and the generation of processing algorithms is up to the systems designer. It is completely feasible to have microprogrammable processors perform such “pre” processing functions as filtering, matrix conversion, transformations, etc.

It is evident that the logistics and maintenance problems associated with a system composed of multiple microprogrammable processors rather than many special purpose hardware devices are greatly minimized. Since each of the functional modules: synchronization, formatting, data compression, and engineering units conversion are all of the same basic hardware type, with only firmware differentiating the function performed by the module; systems maintenance engineers need to be familiar with one type of hardware architecture for all “front-end” equipments. Also, there is the necessity of only handling one line of spare parts for this type of system. Obviously, this system would be less costly to maintain than a system consisting of numerous different hardware boxes; possible all from different vendors.

In conclusion, based on its flexibility and speed., a microprogrammable processor is a prime candidate for the replacement of those functions normally performed by special purpose hardware. The author has been involved with microprogrammable processor designs targeted to replace: A systems disk controller, data compressors, synchronizing units and data bus controllers.

REFERENCES

1. P. M. Davies, Readings in Microprogramming, IABM Systems Journal No. 1, 1972.
2. R. F. Rosin, Contemporary Concepts of Microprogramming and Emulation, Computer Surveys No. 4, 1969, December.
3. M. J. Flynn, D. Maclaren, Microprogramming Revisited, ACM 22nd National Conference Proceedings, 1967.
4. J. Martin, Design of Real Time Computer Systems, Prentice-Hall, 1967.

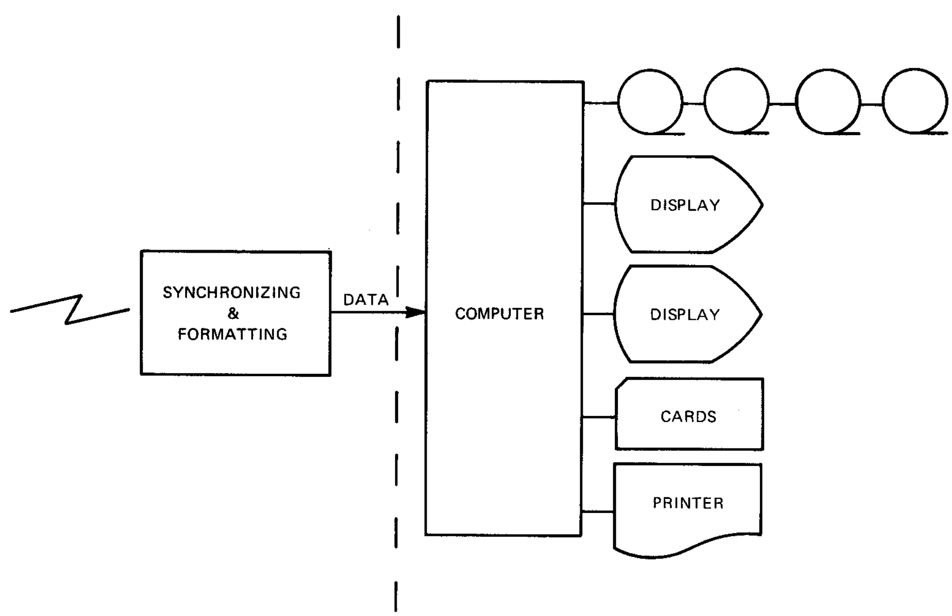

FIG. 1 - CENTRAL PROCESSING SYSTEM

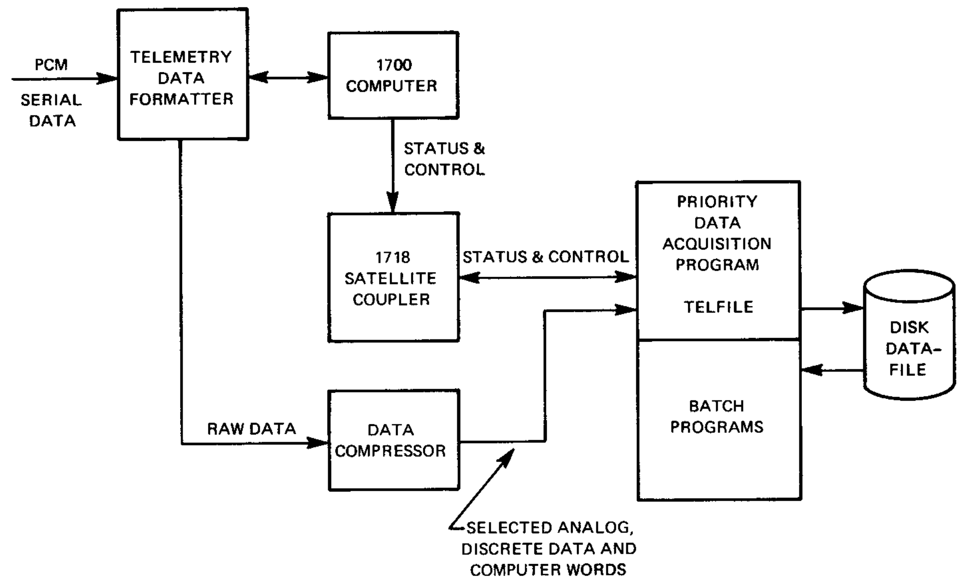

FIG. 2 - CENTRAL PROCESSING SYSTEM

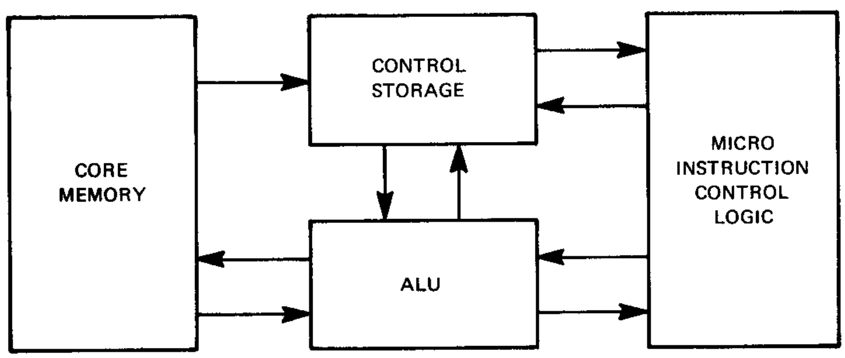

FIG. 3 - MICROPROGRAMMABLE PROCESSOR

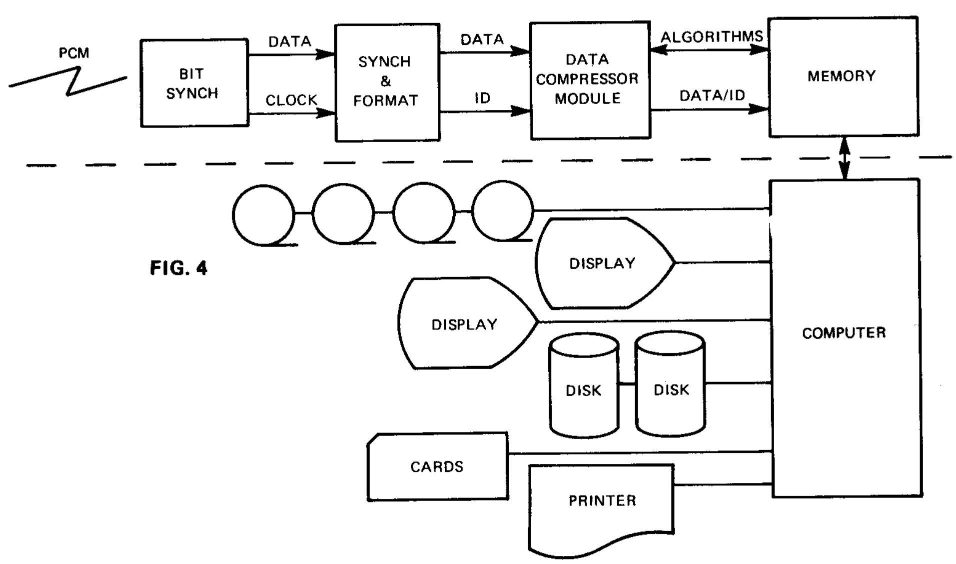

FIG. 4